REPORT DOCUMENTATION PAGE

AFRL-SR-BL-TR-01-

0063

88

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
		01 Apr 99 to 31 Mar 00 Final

4. TITLE AND SUBTITLE
(DURIP 99) Antimonide-Based Miltiple Spectra Infrared Imaging Arrays Grown on GAAS by Compliant Epitxy

5. FUNDING NUMBERS
61103D
3484/US

6. AUTHOR(S)
Dr Hsieh

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
University of Illinois - Urbana Champaign
Department of E&CE
1406 West Green Street
Urbana, IL 61801

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NE
801 North Randolph Street, Rm 732
Arlington, VA 22203-1977

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
F49620-99-1-0156

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. ABSTRACT *(Maximum 200 words)*

The research program consists of formation of a strain-modulated amourphous template and selective area template with a strain-absorbing buried oxide layer formed by lateral oxidation, then develop a two-wavelength infrared imaging array in the 3-8 micron range by integrating $InAs_xSb_{1-x}$ PINs with GaAs driving electronic circuits.

20010221 143

14. SUBJECT TERMS	15. NUMBER OF PAGES
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

Standard Form 298 (Rev. 2-89) (EG)
Prescribed by ANSI Std. 239.18
Designed using Perform Pro, WHS/DIOR, Oct 94

01 NC 031

Report on

"ANTIMONIDE-BASED MULTIPLE SPECTRA INFRARED IMAGING ARRAYS GROWN ON GaAs BY COMPLIANT EPITAXY"

Amount
$200,323.00

Period
March 31, 1999 to March 30, 2000

Prepared for

Air Force Office of Scientific Research
ATTN: NI/DURIP
110 Duncan Avenue, Room B-115
Bolling AFB, DC 20332-8050

Submitted by

The Board of Trustees of the University of Illinois

Professors K. C. Hsieh and K. Y. Cheng
Department of Electrical and Computer Engineering
College of Engineering
University of Illinois at Urbana-Champaign
Urbana, IL 61801

217-244-1806
217-244-6375 (fax)
k-hsieh@uiuc.edu

Date: Oct. 17, 2000

TABLE OF CONTENTS

ANTIMONIDE-BASED MULTIPLE SPECTRA INFRARED IMAGING ARRAYS GROWN ON GaAs BY COMPLIANT EPITAXY

I. RPURCHASE AND INSTALLATION OF REQUESTED INSTRUMENTATION

A. ABSTRACT

The Department of Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign (UIUC) has requested funding support to purchase a Sb-based molecular beam epitaxy (MBE) system to be fitted onto an existing ultra-high vacuum multiple chamber system located at Urbana-Champaign which will be dedicated to support research in DOD-related science and technology. The equipment will be used for several DOD supported research projects, including in particular: (1) Surface engineering for compliant epitaxy, (2) Photonic VLSI and (3) Biological/biochemical optoelectronic sensing system.

The ultimate goal of research (1) is to realize dislocation-free and stress-relaxed lattice mismatched epitaxy growth of different III-V compound semiconductors on various semiconductor substrates across the whole wafer or on selected areas for device integration applications. To demonstrate our efforts in compliant epitaxy, a two-wavelength infrared imaging array in the 3 - 8 μm infrared range will be developed by integrating $InAs_xSb_{1-x}$ p-i-n photodetectors with GaAs driving electronic circuits. It is expected that this technology will lead to the realization of lattice-mismatched heterostructure integration which can be utilized in the next generation of optoelectronic integrated circuits. Thus, the research equipment requested from the DURIP program is a standard Sb-based MBE growth chamber fitted with liquid nitrogen shrouds, a continuous rotation sample manipulator capable of heating the sample to 800°C, molecular beam effusion sources, and a reflection high-energy electron diffraction system.

B. BUDGET OF THE INSTRUMENTATION

1. Instrumentation Information

Type:	Sb-based MBE growth system
Source:	SVT Associates, Inc.
Total cost:	\$318,125.00
Useful life:	≥ 10 years
Contact:	Greg Carpenter, 612-934-2100 Ext-222

2. Cost Summary

(a). Total cost of the Sb-based MBE growth system: \$318,125

i).	Growth chamber with LN_2 paneling	\$75,400
ii).	Linear shutters (6)	\$18,000
iii).	Growth manipulator	\$38,000
iv).	RHEED system	\$19,500
v).	18" pumping well	\$21,300
vi).	Ion pump system	\$18,300
vii).	Transfer rod assembly	\$11,700
viii).	Sb-valved cracking source	\$43,800
ix).	As valved cracking source	\$35,200
x).	30cc Indium cell	\$11,235
xi).	Dopant cells (2)	\$19,690
xii).	Installation (1 week)	\$6,000

(b). Institutional cost sharing: $100,100
- i). In kind (see justification below) $80,100
- ii). Cash $20,000

(c). Equipment Vendor Contributions Through University Discount (7.5%): $17,702

(d). Requested funds from DOD: $200,323

C. PURCHASE ORDER

Unforseen imcompatibility between the in-kind instrumentation hardware with the newly designed growth chamber has prompted some modifications of the design. As a result of the modifications, the requested budget from DOD is insufficient to cover the Sb-valved cracking source. Request for funding support from other resources (e.g. UIUC research board) has been aggressively pursued, and it is pending. The modified design and purchase order (see appendix) has been submitted to the SVT Associates, Inc. on Sept. 7, 1999 with a targeted date of delivery by March 2000.

D. INSTALLATION AND INVOICE

Manufacture of the Sb-based MBE growth chamber was completed in late June, 2000 and it was shipped to the Microelectronics Lab at the University of Illinois at Champaign-Urbana immediately after. The installation of the chamber started on July 17, 2000. With minor adjustments and leak checking, the installation is completed on Aug. 4, 2000. Payment is paid in three terms, and copies of the invoices are included in the appendix.

II. RESEARCH ACTIVITIES AND PROGRESS

A. STRAIN-ABSORBING COMPLIANT EPITAXY

There are two DOD-funded research projects currently performed at PI's group, which will be greatly benefited from the completion and fully functional operation of the requested MBE growth chamber.

Surface Engineering for Compliant Epitaxy

(a) PIs: K. C. Hsieh, K. Y. Cheng, and I. Adesida
(b) Sponsor: Dr. W. Coblenz (DARPA/DSO) and Dr. D. Johnstone (AFOSR)
(c) Budget: 1 Million

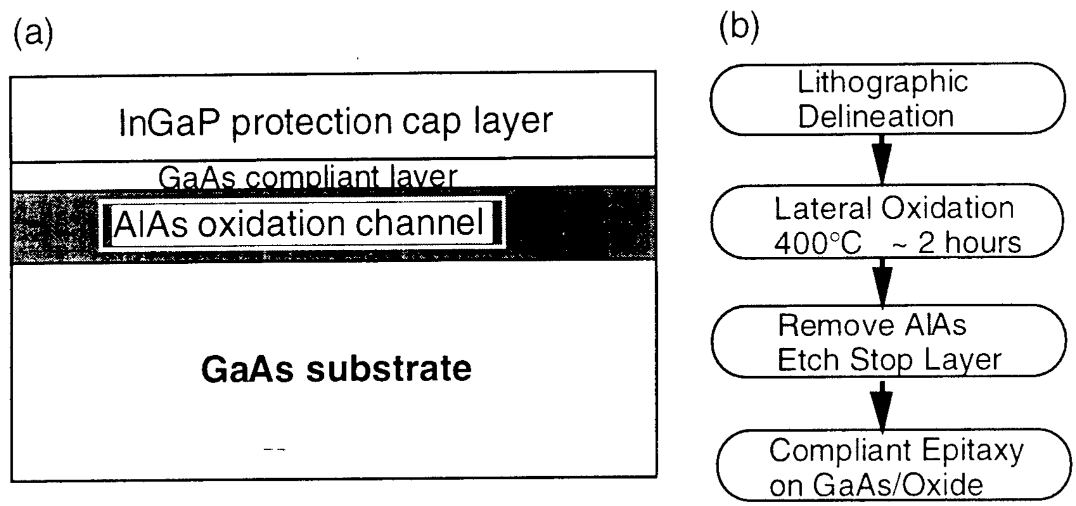
Photonic VLSI

(a) PIs: K.Y. Cheng et al.
(b) Sponsor: Dr. E. Towe (DARPA/ETO)
(c) Budget: 1 Million

Heterogeneous materials or devices integration offers added value to existing devices for various applications. With an increasing demand of high speed communication, it is desirable, for instance, to integrate both InP-based photo detectors an the GaAs-based integrated circuits on the more robust GaAs substrates. The availability of 6" GaAs substrate provides an additional economical incentive. The heterogeneous integration is accomplished either monolithically or with a hybrid approach. For the latter, direct wafer fusion, epitaxial lift-off and other grafting techniques are commonly used. In general, tight processing control is the major concern for the hybrid approach. On the other hand, misfit strain accommodation and device degradation associated with the existence of misfit and threading dislocations in the active region is the limiting factor in the monolithic approach in which mismatched epitaxy is conducted to yield various heterostructures using MBE or MOVPE techniques.

In 1991, Lo has first demonstrated to use a twist-and-bond technique to yield a thin substrate in the order of 100Å which is compliant, i.e. relaxation in strain tolerance and thus an increase of critical thickness is achieved in subsequent mismatched epitaxy. Since then, there have been continuing efforts on both theoretical and experimental work on compliant epitaxy. Fundamentally speaking the key to ensuring compliancy is to realize a thin substrate, the thinner the better. We have accomplished that by conducting surface engineering to generate a strain-

absorbing template for subsequent epitaxy. The strain-absorbing template is formed by laterally wet oxidizing an Al0.98Ga0.02As layer underneath a thin GaAs layer (~100Å). The thin template is to be used for compliant epitaxy where large mistched epitaxy is performed with low dislocation density. In addition, the real estate for epitaxy is expected to be manageble for processing and fabrication of electronic devices. A schematic diagram and flow chart is shown as follows.

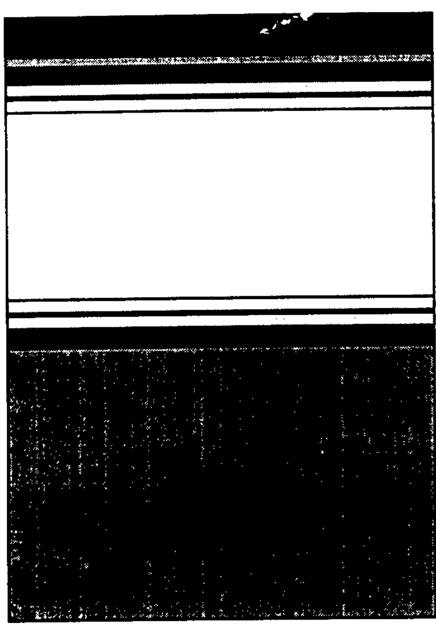


Wet oxidation of AlGaAs has been found sensitive to many factors including layer thickness, aluminum content, oxidation temperature, moisture content. Once oxidation is completed, residual stress within the oxide sometimes leads to layer delamination such that the layer on top of the oxide tends to peel off. The peel off adds complexity to subsequent processing. In addition to residual stress, back stream oxidation up towards surface, although slower in rate, eventually fatally renders the thin GaAs compliant layer to become amorphous during the lateral oxidation process. In general, only polycrystalline structures can be deposited on amorphous substrates. So stress management and implementation of oxidation barrier is critical to the design of compliant template on buried oxide by wet oxidation. With all factors considered, a revised structure of the compliant template is finally obtained shown as follows, and important results and functions of each layer are summarized.

(1) InGaP as an oxidation barrier

Oxidation rate of AlGaAs depends monotonically on the Al content. The same trend holds for InGaAlP compounds. In general, GaAs is rather inert to wet oxidation compared to AlAs, and even higher temperature is needed to oxidize InGaP as compared to oxidation of GaAs. Since InGaP can be grown lattice matched to GaAs with proper In and Ga contents, it is rather advantageous to incorporate InGaP as an oxidation barrier. Results show that InGaP is very

effective to stop wet oxidation either from top or back stream from bottom when lateral oxidation is performed at the temperature range from 400 to 450 C usually taken in our epxeriments. It is found that for wet oxidation less than an hour at 425 C, InGaP of 50Å is thick enough to protect GaAs from oxidation. The thickness may need to increase accordingly if higher temperature or longer period of oxodation is performed.



(2) Graded structure from high Al content oxide channel to neighboring GaAs

Pure AlAs has the highest oxidation rate. It may, however, yield a sharpest transition in composition as well as stress across to the neighboring GaAs. The sharp transition, in turn, gives rise to weakest bonding between the oxide and crystalline GaAs, often leading to delamination. From mechanics point of view, it delaminates in a brittle manner. To minimize that, a mechanism to increase the ductility is desired. A graded structure is one of such solutions as it is known that oxidation drastically reduces with the GaAs content in AlGaAs. We have found that a step graded structure from AlAs to $Al_{0.6}Ga_{0.4}As$ to $Al_{0.3}Ga_{0.7}As$ to GaAs is effective to reduce delamination. Furthermore, use of $Al_{0.98}Ga_{0.02}As$ instead of a pure AlAs is also found effective to increase the toughness for the bonded oxide-GaAs composite, although oxidation rate reduces by half to the pure AlAs. Delamination between the oxide channel and GaAs layer has been rarely seen since a combination of $Al_{0.98}Ga_{0.02}As$ layer with graded structure is implemented. However, all results to date suggest that ultimately it is the incorporation of InGaP which eliminates delamination of the

epitaxial film. Therefore, the function of InGaP is two fold, i.e. oxidation barrier and toughness enhancement.

(3) Development of substitute for $Al_{0.98}Ga_{0.02}As$ oxide channel

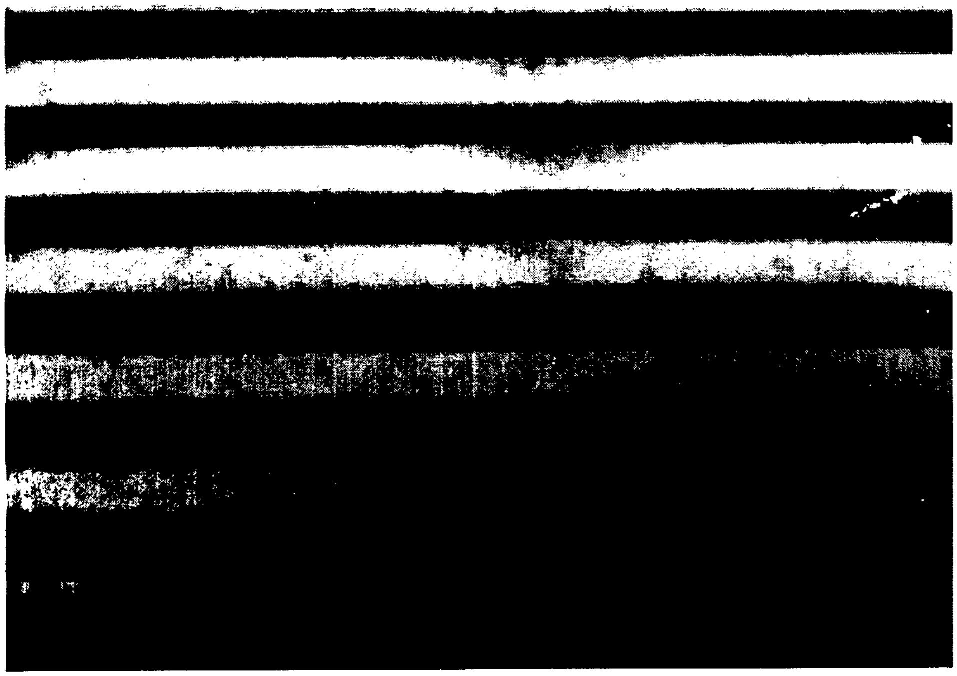
It is found that the oxidation rate of AlGaAs is very sensitive to the Al content especially when it approaches pure AlAs. For example, a mere 2 % decrease in Al content may reduce the oxidation rate in half. Furthermore, over-oxidation for much longer than needed period may actually damage the crystallinity of the GaAs seeding layer due to back stream oxidation upwards. A tight control of oxidation rate is desirable. Therefore, better control of the Al content in the $Al_{0.98}Ga_{0.02}As$ oxide channel is very important, and unfortunately, it is not easy. One of the major reasons is the accuracy of temperature control of the Knuson cell in as MBE system. A few degree change from run to run and day to day operation is common, which may result in one or two percent change in the Al content of an AlGaAs layer easily. To overcome the uncertainty, we have employed a short period superlattice structure consisting of one monolayer of GaAs and 50 monolayers of AlAs. Since each constituent of GaAs and AlAs is binary, stoichiometry is not a concern anymore. In addition, the growth rate of GaAs and AlAs can be accurately monitored with the RHEED intensity oscillation technique. The short-period superlattice structure then gives rise to an average composition of $Al_{0.98}Ga_{0.02}As$. We have also found that the lateral oxidation rate remains the same in the $Al_{0.98}Ga_{0.02}As$ channel if superlattice structure is used instead.

(4) Lattice matched epitaxy on compliant template

To verify the compliancy of the strain-absorbing template, we have first performed regrowth of GaAs/ $Al_{0.3}Ga_{0.7}As$ superlattice on the compliant template. The compliant substrate is obtained by opening 5μm trenches on a 20μm spacing with standard lithographic technique. It is then followed by wet oxidation at 400 or 425 C. After preferentially etching off the InGaP cap layer with HCl, a thin GaAs seeding layer bonded to the underlying InGaP oxidation barrier which in turn is bonded to the oxide channel, is obtained. The substrate is then loaded into the MBE chamber for the regrowth of GaAs/AsGaAs superlattice onto the thin complaint GaAs seeding layer after the surface oxide has first been desorbed at 600 C in vacuum.

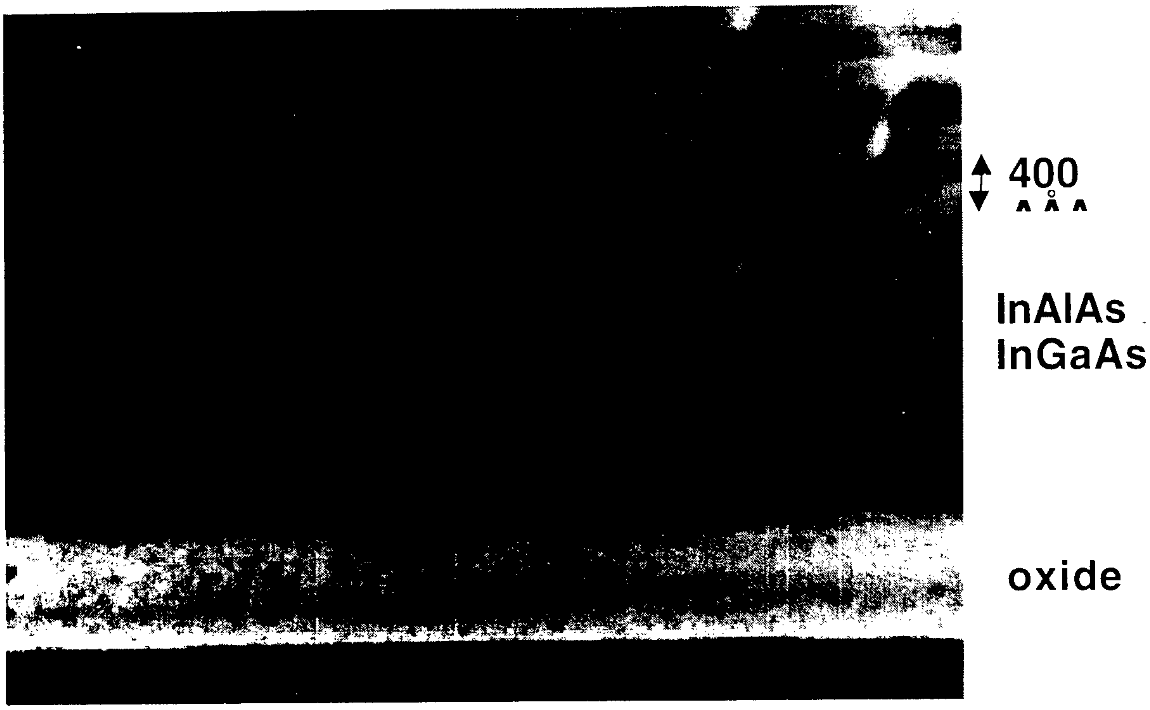
With the incorporation of InGaP oxidation barrier layer, graded structure, and 50:1 short-period superlattices in the $Al_{0.98}Ga_{0.02}As$ channel, we have grown very successfully a GaAs/ $Al_{0.3}Ga_{0.7}As$ superlattice on the 100Å GaAs template. TEM results (below) indicate that sharp AlGaAs/GaAs superlattice is obtained. The crystalline quality has been further confirmed with

photoluminescence measurement. Very high luminescence obtained from the superlattice menifests not only the excellent crystallinity but also the high device quality.



(5) Growth and characterization of strained $In_{0.3}Ga_{0.7}As$ on compliant template

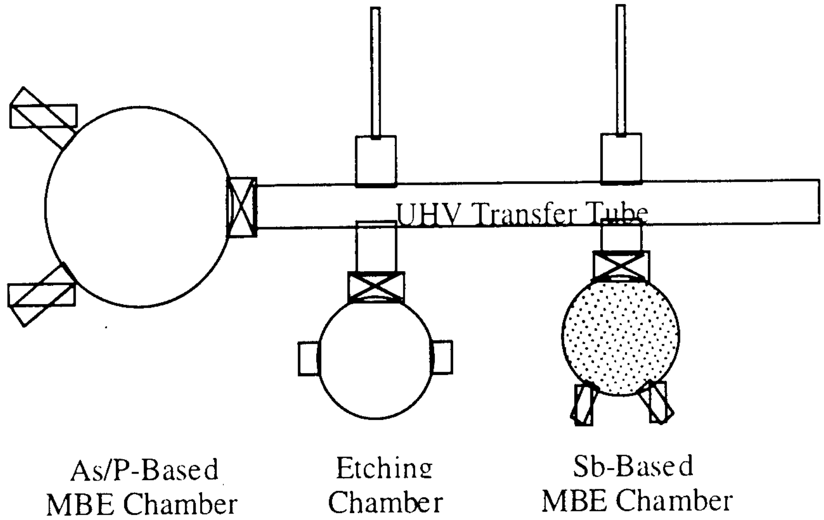
Deposition of bulk $In_{0.3}Ga_{0.7}As$ or $In_{0.3}Al_{0.7}As$/ $In_{0.3}Ga_{0.7}As$ superlattice has been performed. Although a streaky RHHED pattern has been obtained during growth suggesting that a layer by layer growth is taking place, photoluminescence intensity is not strong. TEM analysis indicates that there is still a high density of dislocations in the regrown film. A typical micrograph is shown below. There are several factors leading to the presence of a high density of defects including imperfect morphology in the compliant template, cleanness of the template during desorption and most of all, extent of the compliance of the template. In other words, pin holes in the thin GaAs seeding layer due to wet oxidation, debris and contaminant particles on the GaAs seeding layer due to processing, and inability to plastic flow of the GaAs seeding layer due to strength of the underlying oxide and a strong bond interaction between the two layers. Among the three factors, lack of compliance is the fundamental concern. Continuing effort is underway to evaluate most promising problem-solving approaches, which include (a) stress relaxation of the GaAs template after oxidation, (b) delamination enhancement between the GaAs template and oxide channel, (c) undercut to achieve weak bonding between the GaAs template and oxide channel.



(6) Compliant Epitaxy of Sb-Based Infrared Image Array Structures on GaAs Substrates

Upon the installation of Sb-valved cracking source and further improvement of realizing more compliant template, we will continue to demonstrate wafer-level integration of microwave, digital, and optoelectronic functions relevant to defense applications. The system we choose to demonstrate is a two-wavelength infrared imaging array using p-i-n photodetector structures. The base material for the two-wavelength photodetector is $InAs_xSb_{1-x}$. Depending on the Sb composition, the wavelength can vary from 3 μm in the near infrared range to 8 μm and beyond for the far infrared. Separate GaAs-based electronic devices will be used to process the optical signal received by the $InAs_xSb_{1-x}$ p-i-n photodetector array.

Since the mismatch between InSb and GaAs is about 15%. The demand on compliancy of the thin GaAs strain-absorbing template is even higher than that required in growing InGaAs on GaAs. In case even thinner than 100Å of GaAs is needed to achieve the required compliancy, we plan to further reduce the template thickness by in-situ Cl2 etching coupled with thickness monitoring. The Cl2 etching chamber is coupled with the Sb-based growth chamber by an ultrahigh vacuum transfer assembly as shown below.

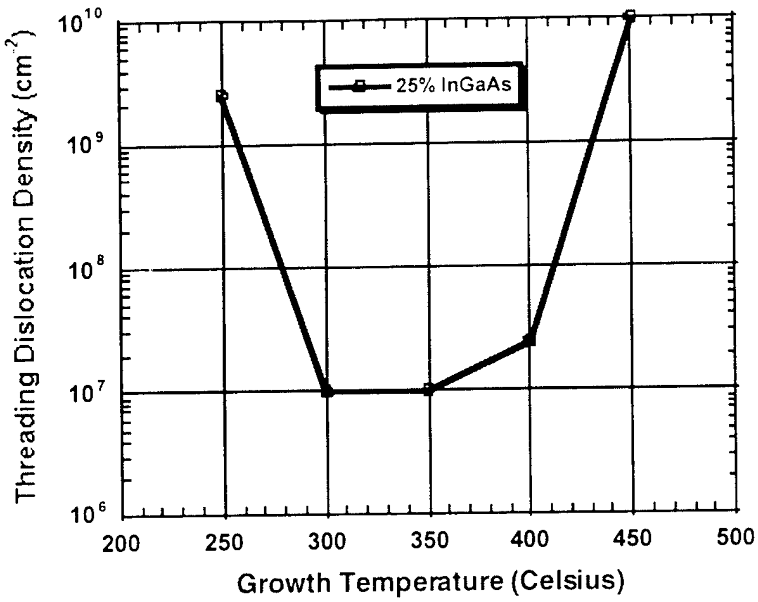


B . STRAIN-RELIEVING METAMORPHIC EPITAXY

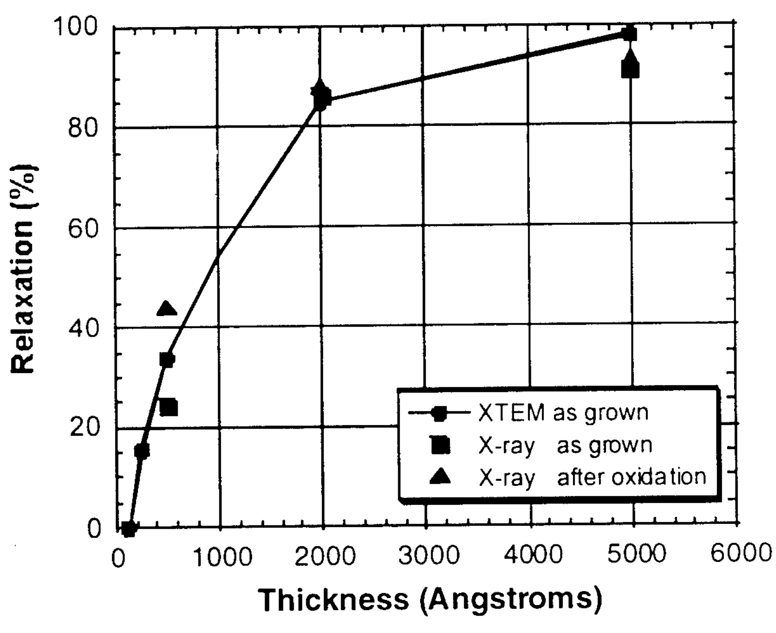
A second approach to reducing the misfit-induced defects in heteroepitaxy is the metamorphic epitaxy technique. It was first reported by Krishnamoorthy et al. that interaction between misfit dislocations and the substrate results in different threading dislocation distributions depending on the magnitude of the misfit strain. As for InxGa1-xAs/GaAs, threading dislocations propagate into the GaAs substrate due to larger shear modulus in InGaAs and weak surface image force for x<18%. As aresult, the defect density of the threading dislocations which exists in the active epitaxial layer is usually low around 10^6/cm^2. For 18%<x<28%, threading dislocations propagates into both the InGaAs epilayer and the GaAs substrate. For x>20%, threading dislocations exclusively exist in the epilayer due to the large image force resulting from the high density of misfit dislocations.

(1) Growth of metamorphic $In_{0.25}Ga_{0.75}As$ on GaAs with low threading defects

We have performed a thorough study of growing $In_{0.25}Ga_{0.75}As$ on GaAs at low temperatures. With an optimized growth condition, threading dislocations as low as ~10^7/cm^2 can be obtained in a film of 4000 Å, which far exceeds theoretical critical thickness. In contrast, threading dislocations in the order of mid 10^{10}/cm^2 exist in conventionally grown $In_{0.25}Ga_{0.75}As$ on GaAs. In fact, the threading dislocation density exhibits a U-shape with respect to growth temperature as shown in the figure. We also found that with the increasing thickness more than 4000Å the strained film can relax more than 90%.



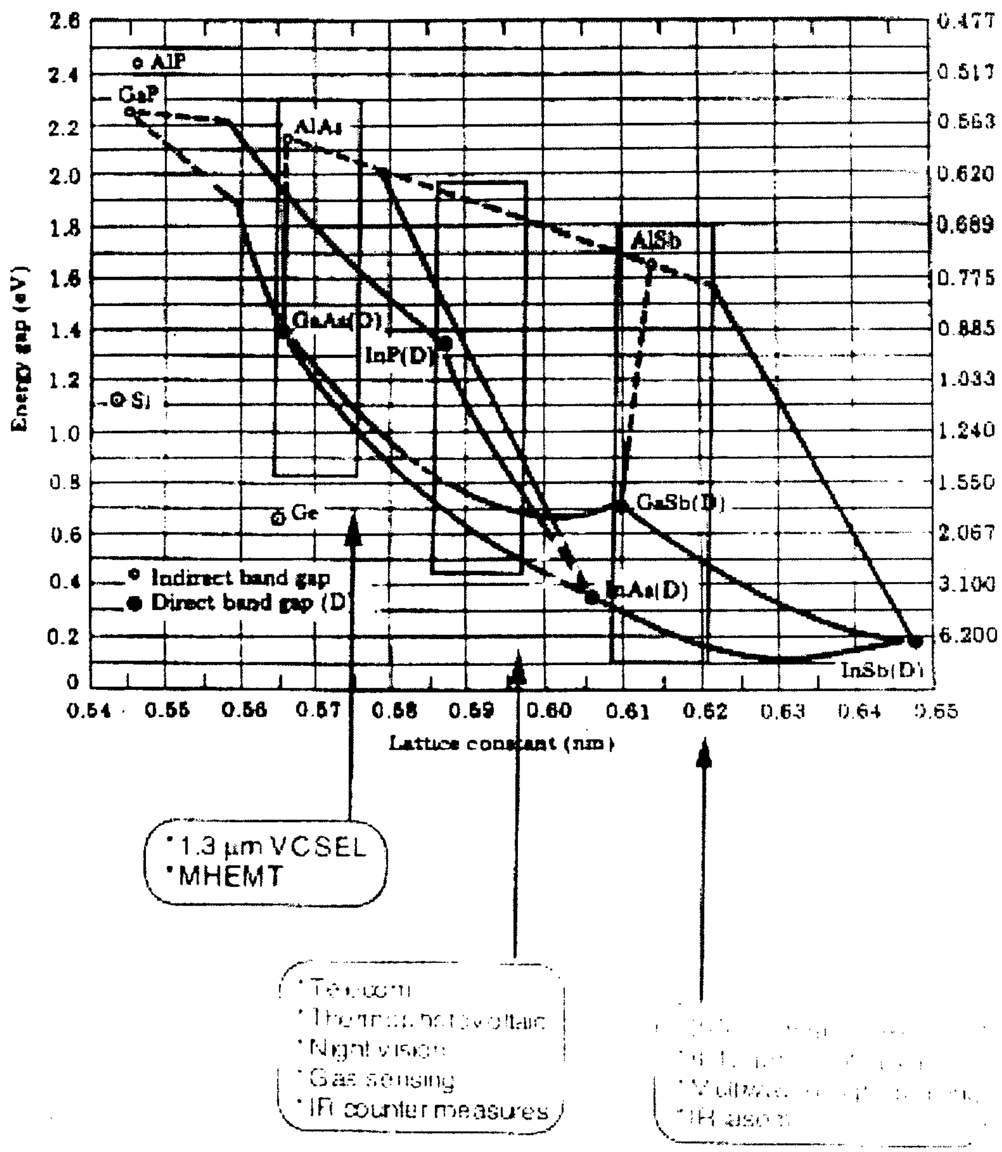
Distribution of threading defects in $In_{0.25}Ga_{0.75}As$ as a function of growth temperature



Strain relaxation in $In_{0.25}Ga_{0.75}As/GaAs$ as a function of film thickness

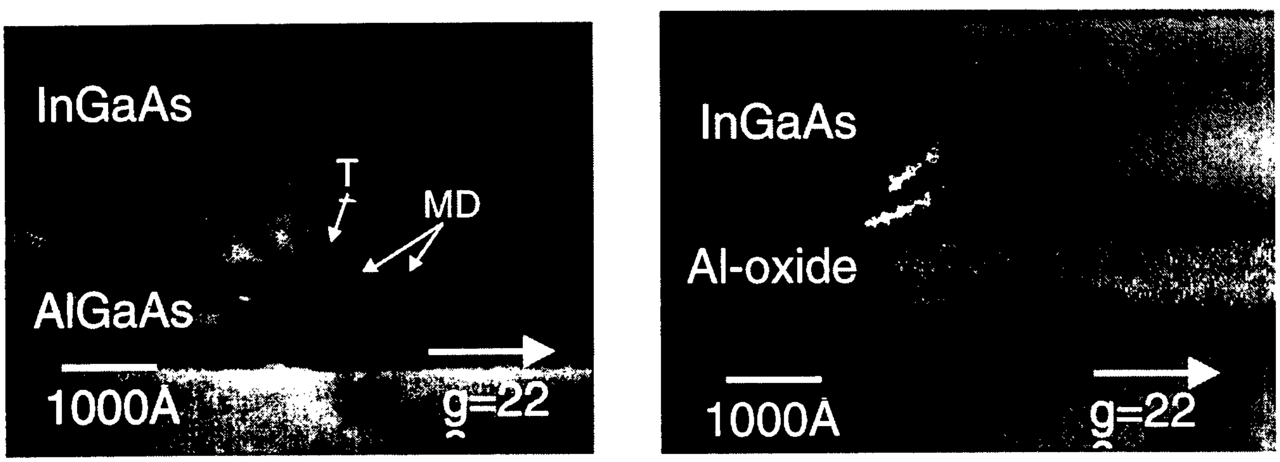
(2) Potential impact on the growth of $In_{0.25}Ga_{0.75}Sb$ on GaSb with low threading defects

The breakthrough in growing $In_{0.25}Ga_{0.75}As$/GaAs with low threading defects is very encouraging. We expect that similar growth optimization procedures will allow us to realize $In_{0.25}Ga_{0.75}Sb$ on GaSb also with low threading defects by MBE growth in the new Sb-based growth chamber. Although $In_{0.25}Ga_{0.75}Sb$ itself is very useful because of its bandgap energy of about 3μm in wavelength which ca be use.! for heat seeking application. more important applications can be benefitted from the growth of lattice matched film of $In_xGa_{1-x}As_ySb_{1-y}$ on the low-defect $In_{0.25}Ga_{0.75}Sb$ template. Other possible applications of this low-defect metamorphic epitaxial growth technique can be seen in the following figure.

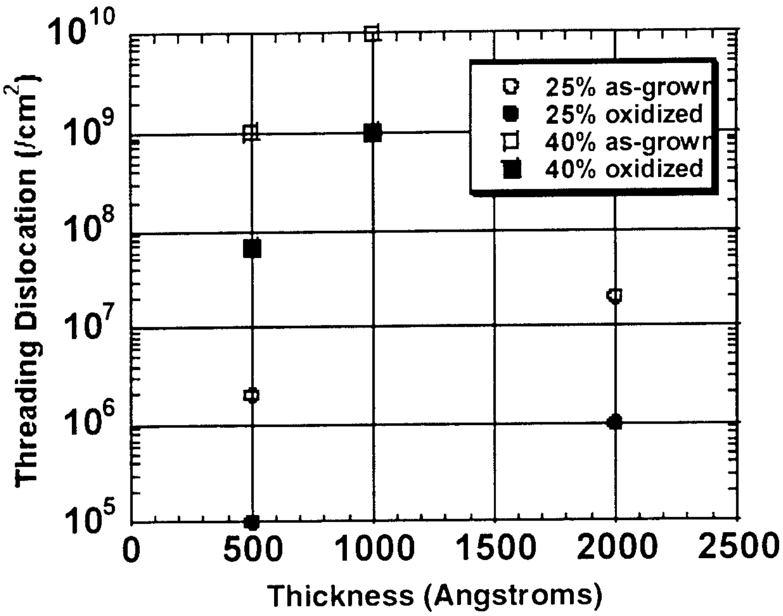


(3) Oxidation-induced defect reduction in strain-relieving metamorphic heteroepitaxy

To further reduce the threading defects in the already low-defect InGaAs film, we have employed the lateral oxidation technique. We first grow an $Al_{0.98}Ga_{0.02}As$ oxidation channel before the deposition of metamorphic $In_{0.25}Ga_{0.75}As$ which has a density of threading defects about $\sim 10^7/cm^2$. After standard lithography to delineate 5μm stripes on 50μm spacing, we have performed wet oxidation and laterally oxidized the underlying AlGaAs oxidation channel. We have found that the threading defects have been reduced to $< 10^6/cm^2$ and a complete elimination of misfit dislocations along the InGaAs/AlGaAs interface have been achieved, as shown in the figure. In addition, reduction of threading dislocations about one order of magnitude shown below and complete elimination of misfit dislocations have also been achieved through lateral oxidation of $In_{0.4}Ga_{0.6}As$. It is expected that optimization of the as-grown to reduce the initial threading dislocation density can lead to device quality substrate for heteroepitaxy of thick $In_{0.4}Ga_{0.6}As$. By applying similar and optimized low-temperature metamorphic epitaxy to yield low defect $In_{0.4}Ga_{0.6}Sb$ to be grown in the new Sb-based growth chamber, we can further reduce the defects by laterally oxidizing the underlying AlGaSb channel. On top of the $In_{0.4}Ga_{0.6}Sb$ template, we can then deposit a high quality $In_xGa_{1-x}As_ySb_{1-y}$ heterostructure device to be used for multiwavelength infrared image array.



TEM micrographs show (left) misfit dislocations along the InGaAs/AlGaAs interface and threading dislocations in the as-grown film. The AlGaAs channel is about 1000Å thick. Upon lateral oxidation, the AlGaAs layer has turned into Al-oxide accompanied with elimination of misfit dislocations and reduced threading defects.



Reduction of threading defects in In0.25Ga0.75As and In0.4Ga0.6As through lateral oxidation of an underlying AlGaAs channel. An order of magnitude of reduction is determined by TEM.

III. PUBLICATIONS AND INTERACTIONS

Three publications related to the proposed compliant epitaxy are listed as follows.

(1) G.W. Pickrell, Jr., K.L. Chang, J. H. Epple, H.C. Lin, D.E. Wohlert, K.C. Hsieh, and K.Y. Cheng, "Improvement of Wet-Oxidized AlxGa1-xAs (x~1) Through the Use of AlAs/GaAs Digitized Alloys," to be published in Appl. Phys. Lett. (000).

(2) K.L. Chang, J. H. Epple, G.W. Pickrell, Jr., H.C. Lin, K.Y. Cheng, and K.C. Hsieh, "Strain relaxation and Defect Reduction in InxGa1-xAs by Lateral Oxidation of an Underlying AlGaAs Layer," to be published in J. Appl. Phys. (2000).

(3) G.W. Pickrell, Jr., K.L. Chang, J. H. Epple, K.Y. Cheng, and K.C. Hsieh, " to be published in J. Vac. Sci. Technol. B (2000).

One conference publication related to the proposed compliant epitaxy has also been presented.

(1) D.E. Wohlert, K.L. Chang, K.C. Hsieh, and K.Y. Cheng, "Improvement of AlAs-GaAs Interface roughness grown with high As overpressures," 18th North American Conference on Molecular Beam Epitaxy, Banff, Canada, October 10-13, (1999).

VI. APPENDIX

Copies of quotation, itemized purchase order and invoices are attached.

Invoice

SVT ASSOCIATES

Solutions Through Epitaxy Engineering

Invoice Number: 2093

Date: 06/30/00

JUL 3 '00
RECEIVED
ACCOUNTING DIV.

Bill To:	Shipped To:
University of Illinois at Urbana Champaign Accounting Division 263 Henry Admin. Bldg. 506 So. Wright Street Urbana, Illinois 61801-3691	University of Illinois at Urbana Champaign Microelectronics Lab 208 N. Wright Street Urbana, IL 61801

P.O. Number	Salesperson	Terms	SVTA Acct
JI45637	GC	Net 30 Days	4459

Date Shipped	Shipped Via	F.O.B.	Quotation #
06/30/00	Vitran Express	Shipping Point	81395R-2

Item	Description	Quantity	Unit Price	Total
1	UHV thin film deposition system 1-2-22147 1-5-21238 [redacted]	1	$ 218,100.00	$ 218,100.00
	Shipping Prepay & Add			$ 1,024.00
	* Please note: Shipping address was changed per request of Technical Contact. request approved by Bill Dielman at (217) 333-3561			

TOTAL AMOUNT DUE 50% Upon receipt of system and approval **$ 110,074.00**

Remit to:
SVT Associates, Inc.
7620 Executive Drive
Eden Prairie, MN 55344

TIN#41-1764876

Via Wire Transfer:
Norwest Bank Minnesota, N.A.
1011 First Street S.
Hopkins, MN 55343
ABA (9-digit transfer number): 091000019
SVT Associates Acct. No.: 3970304068

Invoice

SVT ASSOCIATES

Solutions Through Epitaxy Engineering

Invoice Number: 99125

Date: 10/19/99

Bill To:
Accounting Division
263 Henry Admin. Bldg.
506 So. Wright Street
Urbana, IL 61801-3691
(217) 333-3593

Shipped To:
University of Illinois at Urbana-Champaign
Room 66, Bldg. 37, Mail Code 702
66 Everitt Lab
1406 W. Green
Urbana, IL 61801

P.O #	Salesperson	Terms	SVTA Acct.
JI45637	PPC	Net 30 days	4459

Date Shipped	Shipped Via	F.O.B.	Quote #
10/19/99	Federal Express	Origin	

Item	Description	Quantity	Unit Price	Total
2	10% Upon Design Review	1	$ 21,810.00	$ 21,810.00

1-2-22147-6360 $2,000.00
1-5-21238-6360 19,810.00
$21,810.00

This invoice has been processed for payment
25 9170
B
12-7-99

JI

TOTAL AMOUNT DUE $ 21,810.00

Remit to:
SVT Associates, Inc.
7620 Executive Drive
Eden Prairie, MN 55344

TIN#41-1764876

Via Wire Transfer:
Norwest Bank Minnesota, N.A.
1011 First Street S.
Hopkins, MN 55343
ABA (9-digit transfer number): 091000019
SVT Associates Acct. No.: 3970304068

Electrical and Computer Engineering Department

Req. # :
P.O. #:

REQUISITION

(To be submitted to Room 141 Everitt Laboratory)

Date: 6/28/99

Vendor (Complete Address Needed): SVT Associates, Inc.
7620 Executive Drive
Eden Prairie, MN 55334
(Attn: Mr. Greg Carpenter)

Telephone #: 612-934-2100
Fax #: 612-934-2737
Vendor FEIN #: 41-1764876
Federal Employer Identification Number

Delivery Date:

*If Inv. (X)	Catalog Number	Description	Quantity	Unit Price	Total
X		UHV thin film deposition system	1		$218,100.00
		(See attached detail system description)			
		Grand Total			

User Reference 1 Phone Number ~~333-4053~~ 244-1806
User Reference 2 Phone Number

Account Number 1-5-21238 Account Title F49620-99-1-0156
Amount 198,100— Approved By [signature]

Account Number 1-2-22147 Account Title ECE ICR
Amount 20,000— Approved By [signature]

To be completed by Departmental Business Office

Object Code:

Revised Budget
03/31/99

1. Instrumentation Information

Type:	Sb-based MBE growth system
Source:	SVT Associates, Inc.
Useful life:	≥ 10 years
Contact:	Greg Carpenter, 612-934-2100 Ext-222

2. Cost Summary

(a). Cost Summary (Per Quotation # 80191-R1):		
i).	Growth chamber with LN_2 paneling	\$ 75,400
ii).	Linear shutters (6)	\$ 18,000
iii).	Growth manipulator	\$ 38,000
iv.)	RHEED system	\$ 19,500
v.)	Transfer rod assembly	\$ 11,700
vi.)	Sb-valved cracking source	\$ 37,800
vii.)	As-valved cracking source	\$ 31,200
viii.)	Installation	\$ 6,000
	sub-total	\$237,600
	less vendor discount	- \$17,277
Total equipment cost		\$220,323
(b). Institutional cost sharing:		- \$20,000
(c). Requested funds from DOD:		\$200,323

3. Budget Justification

The UHV Thin Film Deposition System will be assembled by SVT Associates. In addition to the system and options listed alone, several component parts will be supplied by the University of Illinois. These include a 18" diameter stainless steel pumping well, a 400 *l*/s ion pump system, a transfer rod assembly, five power supplies, and five temperature controllers (new). The hardware is in excellent operation condition and can be used for the construction of the Sb-based MBE growth system by SVT Associates, Inc. The current market value of this equipment is \$80,100.

UNIVERSITY OF ILLINOIS

A DEPARTMENT COPY
J145637

PURCHASE ORDER

PURCHASING DIVISION
207 HENRY ADMIN. BLDG.
5^^ SOUTH WRIGHT STREET
2 3-3505
URBANA, ILLINOIS 61801-3564

SHIP TO: UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
Rm: 66 Bldg: 37
66 Everitt Lab
1406 W. Green
Urbana, IL 61801-
Mail Code 702

No. J145637

SHOW THIS ORDER NUMBER ON ALL INVOICES, PACKAGES AND CORRESPONDENCE

BILL TO
ACCOUNTING DIVISION
263 HENRY ADMIN. BLDG.
506 SO. WRIGHT STREET
URBANA, ILLINOIS 61801-3691
PHONE (217) 333-3593

INVOICE IN DUPLICATE

VENDOR FEIN/SSN/TIN	VENDOR PHONE	TYPE CODE	PRINTED DATE	BUYER	P.C.
411-764-876	(612) 934-2100		09/03/1999	Y	E

VENDOR:
S V T ASSOCIATES INC.
GREG CARPENTER
7620 EXECUTIVE DRIVE
EDEN PRAIRIE, MN 55334-

FOB: Shipping Point
SHIP VIA: See Below
TERMS: Check Attached
SOURCE OF PRICE: QUOTE 81395R-2

DESIRED DELIVERY DATE: 03/01/2000 OR SOONER

ADMINISTRATIVE CONTACT		TECHNICAL CONTACT		DEPARTMENT NAME:
Ottie Johnson	(217) 333-0803	K.C. Hsieh	(217) 244-1806	Electrical & Computer Eng

REQUISITION NO.	EOS REF. NO.	COLL/DEPT	COMMODITY CODE	DEPARTMENT ADDRESS:
	259170	22 25		141 Everitt Lab

ITEM	CATALOG NO.	QUANTITY	UNITS	UNIT PRICE	DISCOUNT	AMOUNT
1		1.00	each	$218,100.00	% 0	$218,100.00

DESCRIPTION: UHV thin film deposition system as per quote # 81395R-2 with check attached
40% upon order
10% upon design review
50% upon receipt of system and approval

The attached labor, insurance and indemnity provisions apply to any work performed on University premises and vendor agrees to comply therewith. Vendor is to pay particular attention to the prevailing
wage clause. If prevailing wage requirements are not met, the University may debar your firm (that is remove your firm's name from the active bidders list) for a period of not to exceed two years. Certificate of Insurance must be on file or submitted to the Purchasing Division prior to commencement
of work.

NOTE: High Value Shipments over $5,000 valuation

SEP 7 1999

**CONTACT BILL DIELMAN AT 217/333-3561 OR PEGGY BRAND 217/333-5699 BEFORE SHIPMENT SO INSURANCE CAN BE ARRANGED. IF VENDOR DOES NOT NOTIFY BILL DIELMAN OR PEGGY BRAND PRIOR TO SHIPMENT, THE VENDOR WILL BE RESPONSIBLE FOR THE COST OF REPLACEMENT AND INSURANCE AT NO ADDITIONAL CHARGE TO THE UNIVERSITY.

Note: Call University of Illinois, Purchasing Division, Transportation Section at 217/333-3561 if there are any questions pertaining to these shipping instructions.

TOTAL AMT: $218,100.00

1-2-22147

INVOICE				TRANSPORTATION CHARGES						
PASSED	AMOUNT	PASSED	AMOUNT	DATE	CRS No.	Carrier	Pro. No.	Amt.	Pd.	C

UNIVERSITY OF ILLINOIS

A DEPARTMENT COPY

PURCHASE ORDER

JI45637

ACCOUNT NO		TITLE	USER REFERENCE #1	USER REFERENCE #2	F/O	CUSAS	FUND	SAC	AMOUNT
1-2-22147	6360	ELEC & COMP ENGR REG	Hsieh			1550			$20,000.00
?1238	6360	F49620-99-1-0156	Hsieh			1550			$198,100.00

By Acceptance of this Purchase Order, the contractor certifies that it has provided the University a correct Federal Taxpayer Identification Number and legal status disclosure which is shown on this Purchase Order.

Legal status is: Corporation

INVOICE

TRANSPORTATION CHARGES

\SSED	AMOUNT	PASSED	AMOUNT	DATE	CRS No.	Carrier	Pro. No.	Amt.	Pd.	C

UNIVERSITY OF ILLINOIS

PURCHASE REQUISITION

Dept Req No.

EOS Req. No. 259170

Request Date	Desired Delivery Date
06/29/1999	07/13/1999

P-Code	Source of Price	Vendor Number
E		411-764-876

Dept Name & Mailing Address	Campus/Coll/Dept	Shipping Address	Preferred Vendor
Electrical & Computer Eng Electrical & Computer Eng 141 Everitt Lab 217-244-1949	1 22 25 Alpha Code: JI Mail Code: 702	UNIVERSITY OF ILLINOIS Rm: 66 Bldg: 37 66 Everitt Lab 1406 W. Green Urbana, IL 61801-	SVT ASSOCIATES INC. GREG CARPENTER 7620 EXECUTIVE DRIVE EDEN PRAIRIE, MN 55334

Administrative Information	Phone	Technical Information	Phone	Vendor Contact
Ottie Johnson	(217) 333-0803	K.C. Hsieh	(217) 244-1806	

Requested By	Approved By	Vendor Phone	Vendor Fax Number
DAWN COREY		(612) 934-2100	(612) 934-2737

FOR CPOs ONLY. Maximum Total Expenditure (if applicable) $.00 Authorized Period Until Terminated

ITEM	CATALOG NO.	QUANTITY	UNITS	UNIT PRICE	DISCOUNT	AMOUNT
1		1.00	each	$218,100.00	% 0	$218,100.00

DESCRIPTION: UHV thin film deposition system

TOTAL AMT: $218,100.00

ACCOUNT NO		TITLE	USER REFERENCE #1	USER REFERENCE #2	F/O	CUSAS	FUND	SAC	AMOUNT
1-2-22147	6300	ELEC & COMP ENGR REG	Hsieh			1550			$20,000.00
1-5-21238	6300	F49620-99-1-0156	Hsieh			1550			$198,100.00

12/7/99
2nd Payment
$21,810.00

INVOICE

PASSED	AMOUNT	PASSED	AMOUNT

TRANSPORTATION CHARGES

DATE	CRS No.	Carrier	Pro. No.	Amt.	Pd.	C

UHV Thin Film Deposition System Description

The research equipment requested is a ultra-high vacuum thin film deposition system which consists of an 18" diameter MBE growth chamber fitted with liquid nitrogen shrouds, a continuous rotation sample manipulator capable of heating the 3" sample to 800°C, a sample transfer rod assembly, electron-beam molecular beam sources, a reflection high-energy electron diffraction system, UHV pumping systems and control console, related electronics and rack, and ports for multiple effusion cells, shutters, and diagnostic systems. This system will be connected to the existing UHV transfer tube made by SVT and the Perkin-Elmer MBE system.

An 18" diameter stainless steel pumping well, a 400 *l*/s Varian ion pump system and power supply, and a 2000 l/s CTI cryopump will be provided by us to the vendor for the construction of the system.

SOLE SOURCE LETTER

June 28, 1999

Purchasing Department
University of Illinois
MC-364

To whom it may concern:

This letter concerns the purchase of a custom-designed ultra-high vacuum (UHV) thin film deposition equipment from SVT Associates, Inc. (hereafter SVT) for the total amount of $218,100 (see attached quote and requisition). The purpose of this letter is to confirm that SVT is the only viable manufacturer capable of providing these items.

The equipment specified on the following pages is required to use with UHV apparatus, currently consisting of a Perkin-Elmer molecular beam epitaxy (MBE) chamber, an etching chamber, and a SVT transfer tube. This system is located in the clean room facility at the Microelectronics Laboratory Building. The proposed purchase is for a UHV thin film deposition system to be connected to the existing UHV apparatus via the SVT transfer tube. The entire UHV system is based on Perkin-Elmer design. Thus, contractors must thoroughly knowledgeable with these specifications. Perkin-Elmer itself no longer manufactures MBE systems, but has transferred all of its MBE-related technology to SVT (see attached letter dated August 26, 1991). Consequently, SVT is the only authorized manufacturer for parts compatible with existing Perkin-Elmer MBE systems. Due to the complex and highly critical nature of this UHV thin film deposition system, allow an unauthorized and inexperienced vendor to attempt to meet the specifications for this equipment would present a profound financial risk, and would therefore be unwise. This provides the justification for the sole source assertion.

SVT is presently the sole authorized manufacturer of parts for Perkin-Elmer MBE systems. In view of the specific requirement for critical UHV system compatible with an existing Perkin-Elmer 430 MBE system, in my judgment, it is neither necessary nor appropriate to submit this item for bid.

Sincerely,

K.C. Hsieh, Associate Professor
Electrical and Computer Engineering
244-1806
k-hsieh@uiuc.edu

SVT ASSOCIATES

Solutions Through Epitaxy Engineering

A BLT Company

University of Illinois - Urbana

UHV Thin Film Deposition System

Quotation # 81395R-2

UHV Thin Film Deposition System Consisting Of:

Growth Chamber with LN2 Paneling
- Growth Chamber
- LN2 Cryopanel
- Viewports and Blanks

Vacuum Console & Electronics Rack
- Vacuum Console
- New Bottom Dome
- Electronics Rack

Growth Manipulator
- 3" Growth Manipulator, 1000 C, Rotation
- 3kV Power Supply
- Eurotherm Controller
- Cables

Transfer Rod Assembly
- Magnetic Transfer Rod
- Substrate Transfer Fork Assembly

7cc Multi-pocket E-Beam Evaporator
- 7cc Four Pocket E-Beam Evaporator
- LN2/Water Panel with Shutter
- Power Supply, Controller & XY Sweep

RHEED System
- 10keV RHEED Gun
- 10keV RHEED Gun Control
- RHEED Power Supply Cable
- RHEED Screen
- 8" Viewport
- RHEED Screen Shutter

System Pumping
- Refurbish Existing 2000l/s Cryopump
  (Change O-ring Flange to 10" Conflat Flange)
- 10" Manual Gate Valve
- Refurbish Existing Varian Ion Pump
- Used 8" Manual Gate Valve

Assembly and Checkout of the System at SVTA

1 Week of Installation

Total System Price: *$235,300*

7.5% University Discount + $6,000 Installation *$218,100*

SVT Associates, Inc. • 7620 Executive Drive • Eden Prairie, MN 55334 USA • Ph. 612-934-2100 • Fax 612-934-2737

Options For Consideration w/7.5% Discount

(Qty 6) Linear Shutters $16,650
Magnetically Coupled
Soft Action

System Bakeout $12,488

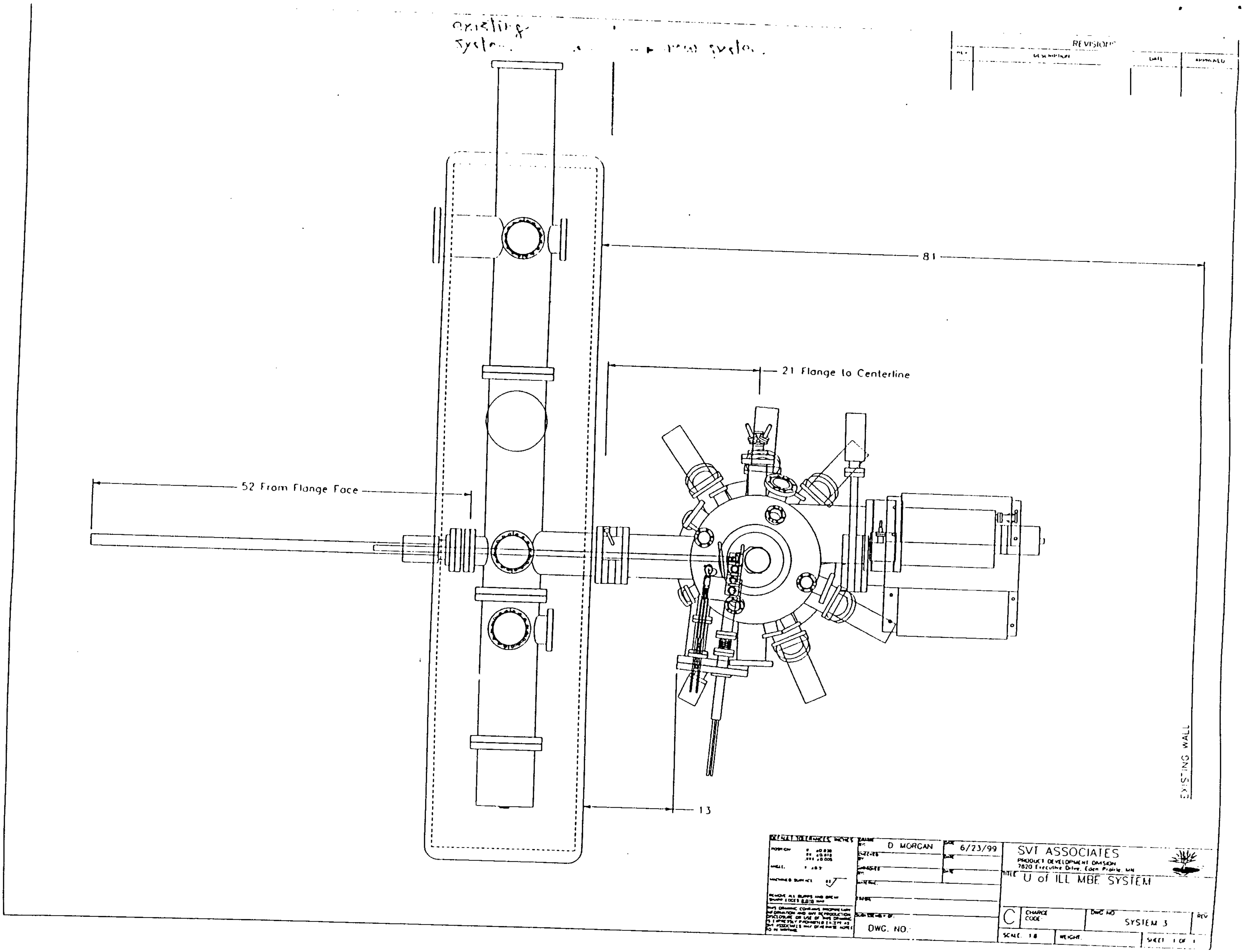
Quartz Crystal Monitor and Controller $5,920

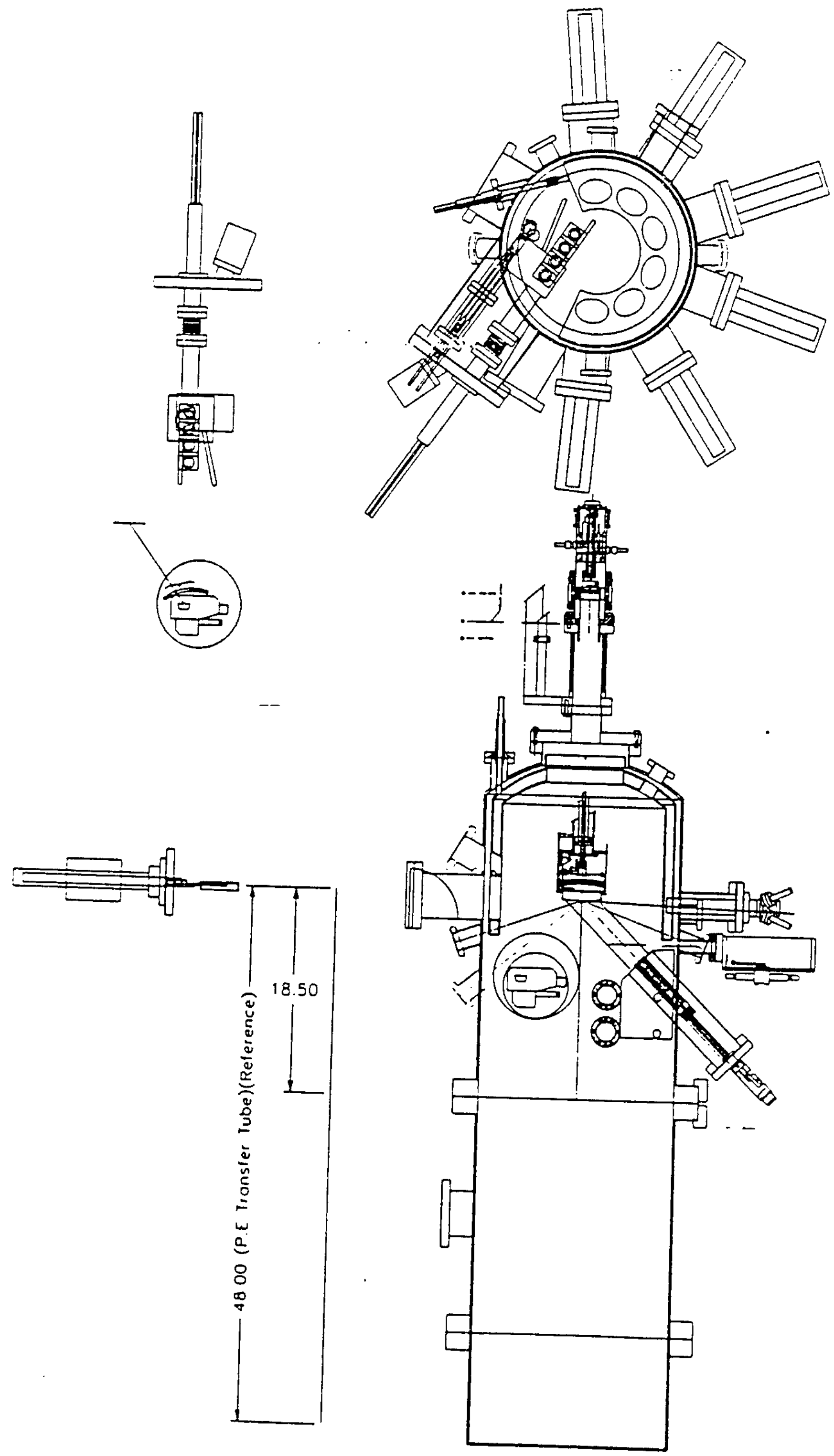
(If Installation Runs Longer Than 1 Week, A Rate of $1,200 Per Day Will Be Incurred)

Terms And Conditions:

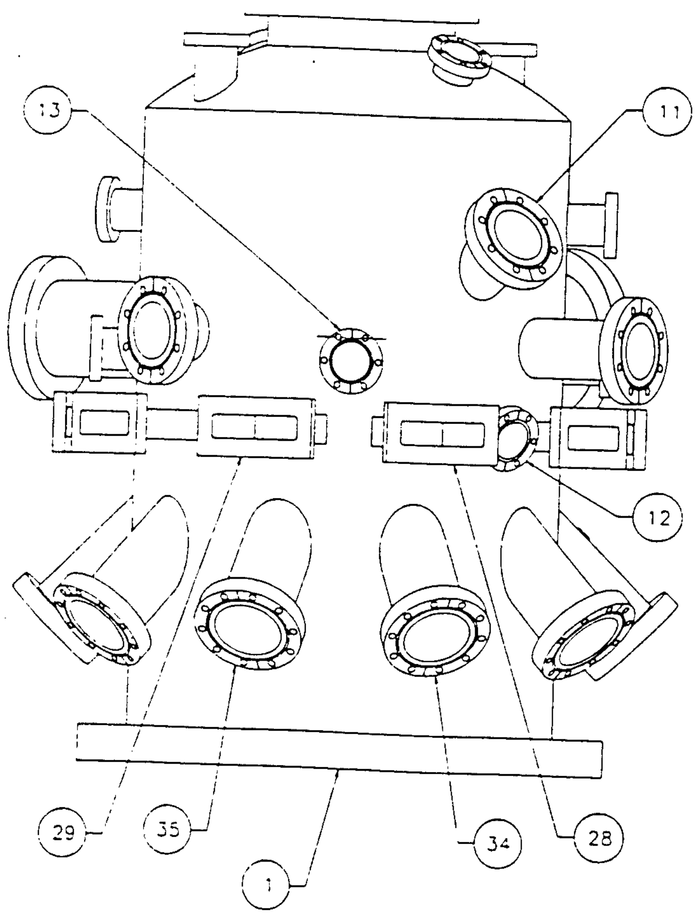
Quotation Date:	**June 15, 1999**
Quotation Valid For:	**60 Days**
Payment Terms:	**40% Upon Order** **10% Upon Design Review** **50% Upon Shipment**
FOB:	**SVTA, Eden Prairie, Minnesota** **(Prepay and Add)**
Delivery:	**6 Months ARO**
Shipment Method:	**Best Way**

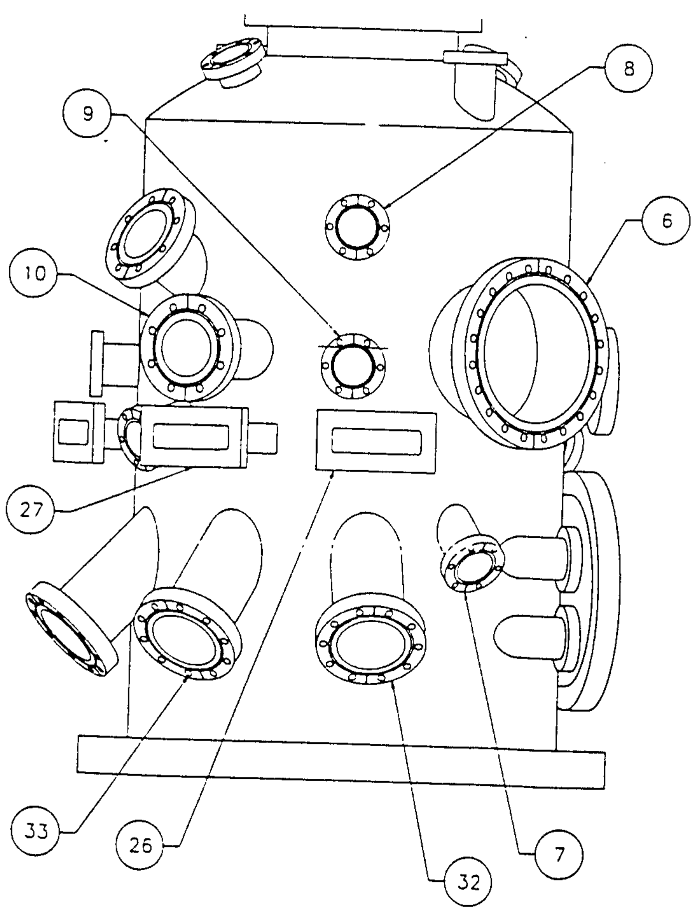
Greg Carpenter
Systems Manager

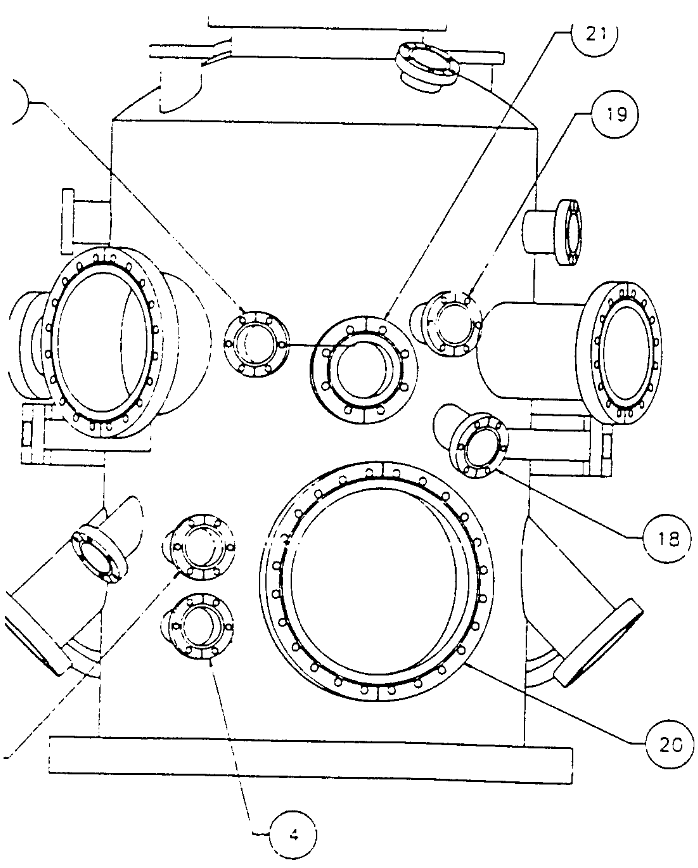

existing system
new system
REVISIONS
DESCRIPTION
DATE
APPROVED
81
21 Flange to Centerline
52 From Flange Face
13
EXISTING WALL
DEFAULT TOLERANCES INCHES
D MORGAN
6/23/99
SVT ASSOCIATES
PRODUCT DEVELOPMENT DIVISION
7620 Executive Drive, Eden Prairie, MN
TITLE U of ILL MBE SYSTEM
C
CHARGE CODE
DWG NO
SYSTEM 3
REV
DWG. NO.
SCALE 1:8
WEIGHT
SHEET 1 OF 1

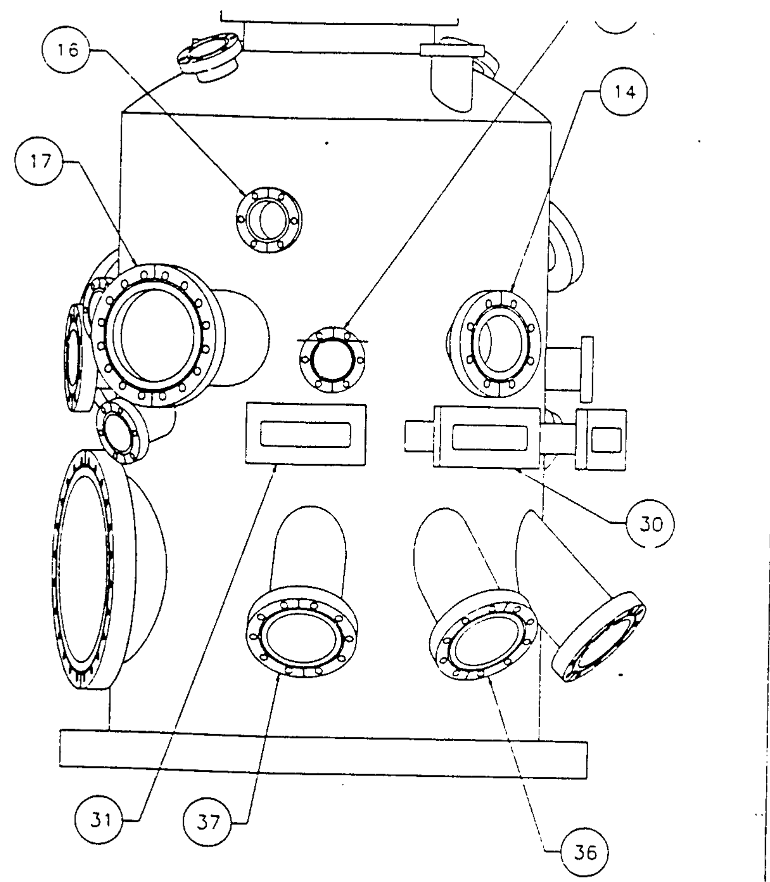


D. MORGAN	6/23/99	SVT ASSOCIATES PRODUCT DEVELOPMENT DIVISION	
		TITLE: U of ILL MBE CHAMBER, MULTI-SECTION VIEW	
DWG. NO.:		C	DWG NO.: SECTION3
		SCALE: 1:8	WEIGHT:	SHEET: 1 OF 1


13
11
12
29
35
1
34
28


9
8
6
10
27
7
33
26
32





DRAWN BY: D. MORGAN	DATE: 5/12/99	SVT ASSOCIATES PRODUCT DEVELOPMENT DIVISION 7620 Executive Drive, Eden Prairie, MN	
MATERIAL: 304L SSTL		TITLE: MBE CHAMBER	
FINISH: ELECTROPOLISH		D	CHARGE CODE
DWG. NO		DWG NO.: PROTOTYPE	REV

SVT ASSOCIATES	CHAMBER PORT SCHEDULE	DRAWING NO: PROTOTYPE	REVISION: Original
TITLE: MBE CHAMBER	DRAWN BY: D. MORGAN · DRAWN DATE: 5/12/99	APPROVAL DATE:	SHEET: 1 of 2

PORT NO.	FLANGE SIZE	ROT	TUBE SIZE OD x THK.	PORT LENGTH	LOC. TOL.	FOCAL HEIGHT	THETA (O)	ALPHA (α)	OFF SET (X)	ROT. (R)	PORT DESCRIPTION	NOTES
1	NOTES	NO	18 0 x 187									
2	10" CF	NO	8 0 x 125								SOURCE FLANGE (FLAT SURFACE)	SEE NOTE #1
3	2 75" CF	NO	1 75 x 063								STAGE MOUNTING PORT	N/A
4	2.75" CF	NO	1 5 x 063								VIEW PORT	N/A
5	2.75" CF	NO	1.5 x 063								LN2 FEEDTHRU (LOWER INPUT)	N/A
6	3" CF	YES	6 0 x 094								LN2 FEEDTHRU (LOWER OUTPUT)	N/A
7	2 75" CF	NO	1 5 x 063								SAMPLE INTRODUCTION	N/A
8	2.75" CF	NO	1 75 x .063								VIEWPORT	N/A
9	2.75" CF	NO	1 75 x .063								INTERIOR LIGHTING PORT	N/A
10	4.5" CF	NO	2 5 x .063								OPTICAL FLUX MONITORING PORT #1	APPOSING ALIGNMENT WITH PORT 15
11	4 5" CF	NO	2 5 x 063								RHEED GUN	APPOSING ALIGNMENT WITH PORT 17
12	2 75" CF	NO	1 75 x 063								VIEW PORT	N/A
13	2.75" CF	NO	1.75 x .063								ELLIPSOMETRY PORT #1	CRITICAL ALIGNMENT WITH FOCAL PT
14	4.5" CF	NO	2.5 x .063								FLUX BEAM MONITORING PORT	N/A
15	2.75" CF	NO	1.75 x .063								VIEW PORT	N/A
16	2.75" CF	NO	1.75 x .063								OPTICAL FLUX MONITORING PORT #2	APPOSING ALIGNMENT WITH PORT 9
17	6" CF	NO	4 0 x 063								ION GAUGE	N/A
18	2.75" CF	NO	1 75 x .063								RHEED SCREEN	APPOSING ALIGNMENT WITH PORT 10
19	2.75" CF	NO	1.5 x .063								ELLIPSOMETRY PORT #2	CRITICAL ALIGNMENT WITH FOCAL PT
20	10" CF	NO	8 0 x .125								OCM	N/A
21	4.5" CF	NO	2.5 x .063								E-BEAM PORT	N/A
22	2.75" CF	NO	1 5 x 063								QUADRAPOLE MASS SPEC.	N/A
23	2.75" CF	NO	1.5 x .063								LN2 FEEDTHRU (UPPER INPUT)	N/A
											LN2 FEEDTHRU (UPPER OUTPUT)	N/A

SVT ASSOCIATES	CHAMBER PORT SCHEDULE	DRAWING NO PROTOTYPE		REVISION Original
TITLE: MBE CHAMBER	DRAWN BY: D. MORGAN	DRAWN DATE: 5/12/99	APPROVAL DATE	SHEET 2 of 2

PORT NO.	FLANGE SIZE	ROT.	TUBE SIZE OD x THK.	PORT LENGTH	LOC. TOL.	FOCAL HEIGHT	THETA (Θ)	ALPHA (α)	OFF SET (X)	ROT. (R)	PORT DESCRIPTION	NOTES
24	2.75" CF	NO	1.75 x .063								VIEW PORT (TOP DOWN VIEW)	N/A
25	2.75" CF	NO	1.75 x .063								VIEW PORT (TOP DOWN VIEW)	N/A
26.	NOTES	N/A	4 x 1.25 x .12								SHUTTER PORT #1	SEE NOTE #2
27	NOTES	N/A	4 x 1.25 x .12								SHUTTER PORT #2	SEE NOTE #2
28	NOTES	N/A	4 x 1.25 x .12								SHUTTER PORT #3	SEE NOTE #2
29	NOTES	N/A	4 x 1.25 x .12								SHUTTER PORT #4	SEE NOTE #2
30	NOTES	N/A	4 x 1.25 x .12								SHUTTER PORT #5	SEE NOTE #2
31	NOTES	N/A	4 x 1.25 x .12								SHUTTER PORT #6	SEE NOTE #2
32	4.62" CF	NO	3.0 x .063								SOURCE PORT #1	WATER COOLING AROUND TUBE
33	4.62" CF	NO	3.0 x .063								SOURCE PORT #2	WATER COOLING AROUND TUBE
34	4.62" CF	NO	3.0 x .063								SOURCE PORT #3	WATER COOLING AROUND TUBE
35	4.62" CF	NO	3.0 x .063								SOURCE PORT #4	WATER COOLING AROUND TUBE
36	4.62" CF	NO	3.0 x .063								SOURCE PORT #5	WATER COOLING AROUND TUBE
37	4.62" CF	NO	3.0 x .063								SOURCE PORT #6	WATER COOLING AROUND TUBE

NOTES:

1. FLANGE IS FOR USE WITH A HELICOFLEX METAL SEAL (P/N). THIS FLANGE IS SIMILAR TO A 18" WIRE SEAL TYPE, IN O.D., I.D., AND BOLT CIRCLE. FLANGE IS FITTED WITH M12 X 1.25 SSTL HELICOIL THREADED INSERTS. DETAILED DIMENSIONS OF FLANGE CAN BE FOUND ON DRAWING NO. 500XXXX.

2. SEE DRAWING NO. 5000016 FOR DIMENSIONS OF RECTANGULAR FLANGE. FLANGE USED WITH HELICOFLEX METAL SEAL (P/N).

3. DETAILED DIMENSIONS OF PORT LOCATION CAN BE FOUND ON DRAWING NO. 500XXXX.